Atmospheric Forcing and the Structure and Evolution of the Upper Ocean in the Bay of Bengal

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LONG-TERM GOALS

Our long-term goals are to improve understanding and simulation of physical processes in the upper ocean that influence air-sea interaction and the upper-ocean environment. The focus of this project is an investigation of the processes that determine the vertical structure and evolution of the upper ocean in the southern Bay of Bengal. The Bay of Bengal is an interesting region from the perspective of air-sea interaction: the presence of a salinity-stratified barrier layer is believed to have important effects on the sea surface temperature field and the regional atmosphere because the shallow stratification favors a relatively rapid response of the upper ocean to surface forcing. The strong, shallow stratification in the region and the dynamical processes governing the upper-ocean structure and air-sea interaction have not yet been adequately characterized and understood, posing a challenge to the ability of numerical models to simulate and predict changes in the ocean and atmosphere there. With this project, we seek to use new and existing measurements to test, scrutinize, and improve the conceptual, theoretical, and dynamical constructs of air-sea interaction in the Bay of Bengal.

OBJECTIVES

The present effort involves inter-related observational components:

(1) Analysis of new and historical field observations and satellite data to improve understanding of air-sea interaction and upper-ocean dynamics in the presence of the barrier layer. As a part of this effort, the PIs have been participating in planning meetings and meetings geared at strengthening ties with international partners, including scientists and officials from Sri Lanka and India.

(2) Participation in research cruises to perform high-resolution (2-km horizontal, 1-m vertical) sampling of upper-ocean structure using an Underway CTD (UCTD).

(3) Deployment of an oceanographic surface mooring to provide a detailed view of the forcing and evolution of the complex upper-ocean stratification in the region. The mooring will carry instrumentation for high-quality estimates of surface fluxes and high-resolution vertical profiles of temperature, salinity, and velocity over the upper 100 m. The mooring will be able to carry instruments for other investigators.

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APPROACH

During cruises in the Bay of Bengal in November and December 2013, we deployed an "Underway CTD" instrument (manufactured by Oceanscience of Carlsbad, CA) to measure vertical profiles of temperature and conductivity (salinity) from a moving vessel. The UCTD system (Figure 1) consists of a 2-kg instrument and a small electric winch; spectra line is wound on the instruments tailspool, and the winch is allowed to freespool, so that the instrument can be dropped from the stern of the ship and fall directly downward at a constant speed while the ship is underway. For temperature/salinity profiles of the upper 400 m of the ocean, casts can be repeated about every 15 minutes, giving a horizontal resolution of about 3.7 km at a ship speed of 8 knots. The horizontal resolution can be increased or decreased by varying the ship speed.

Our research group participated in two cruise legs in the Bay of Bengal during November/December 2013, with three people on each leg to lead 24-hour UCTD operations. We prepared and sent two complete UCTD systems to ensure against mechanical failures. Cruise participants from India and Sri Lanka were trained to stand watch and assist in UCTD operations.

Later during this project (anticipated for FY2015), we will deploy a heavily instrumented air-sea interaction mooring to collect measurements of the air-sea exchange of heat, momentum, and freshwater and the coincident evolution of the upper ocean. Because of the needs of the larger DRI and the measurements planned by Indian colleagues, we have modified our original plan for a short-term deployment (~50 days) to instead perform a longer, one-year deployment near 18°N, 90°E. Much of our focus during the past year has been on preparing this mooring for deployment in November/December 2014 from the Indian Oceanographic Research Vessel *Sagar Nidhi*.

Part of our approach for getting the most "bang for the buck" from this effort has been to partner with Indian colleagues (especially D. Sengupta of the Indian Institute of Science, M. Ravichandran of the Indian National Centre for Ocean Information Services, and R. Venkatesan of the National Institute of Ocean Technology) to conduct our fieldwork more efficiently in the region and to develop a plan to deploy an almost identical, India-funded surface mooring. As a result of this partnership, we will be deploying our surface mooring from the ORV *Sagar Nidhi* this fall with only two WHOI mooring technicians, and there will be two full years of high-quality surface-flux data available for addressing the scientific questions and goals of the ASIRI DRI.

WORK COMPLETED

Work on this project began in April 2013. During the past year, we performed fieldwork during November-December 2013 aboard the RV *Roger Revelle*. Our Underway CTD measurements provide a key data set on the spatial variability of temperature and salinity in the Bay of Bengal, with fine vertical (~1 m) and horizontal (2-10 km) resolution. We have performed quality control on the UCTD data, and we have used the shipboard meteorological data to estimate the air-sea fluxes of momentum, heat, and freshwater; these two data sets have been distributed to other DRI investigators and international partners.

Another major area of effort during the past year has been preparation of a heavily instrumented surface mooring for deployment near 18°N, 90°E. All gear and instruments are now in transit to Chennai, India, where it will be loaded on the ship. Two members of our group (R. Weller and J. Lord) traveled to Chennai, India during June 2014 to solidify our partnerships and coordinate logistics.

We have also participated in meetings to build partnerships with colleagues from India and Sri Lanka and in meetings to plan and refine the overall measurement program for the ASIRI DRI. As a part of the planning effort, we have begun analysis of available in situ and satellite data to refine our hypotheses about the role of the shallow upper-ocean stratification in air-sea interaction in the region.

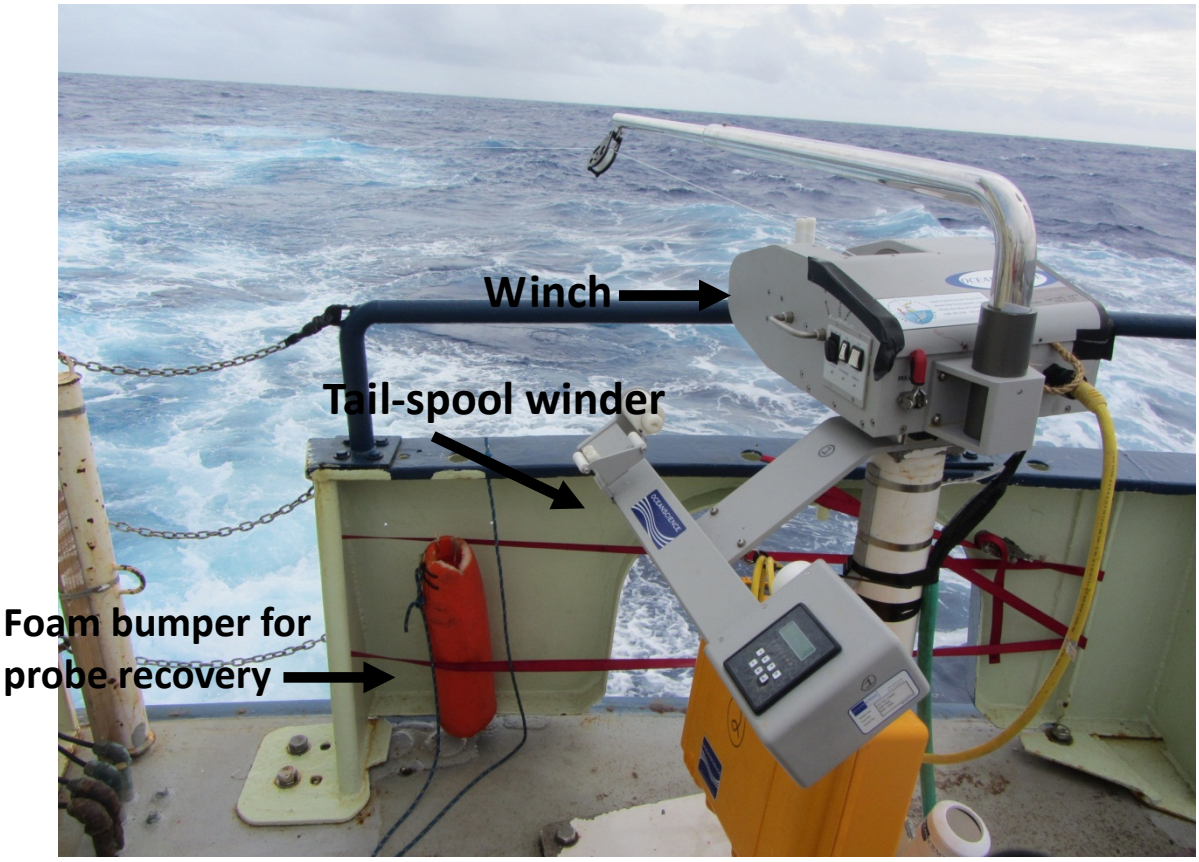

Figure 1: UCTD system during deployment on the port side of the *Knorr's* fantail.

RESULTS

Our UCTD systems provided unique, high-resolution measurements of upper-ocean temperature and salinity, with a total of 2940 CTD casts being collected during the two cruise legs in November/December 2013. An example of the data from the second cruise leg is shown in Figure 2. These data are being utilized by many other investigators in the ASIRI DRI; for example, the data factored prominently into the initial overview article on the program (Lucas et al., 2014).

For the surface-mooring component of this project, all of the work to date has been focused on preparing for the upcoming fieldwork and installation of the mooring during November/December 2014, and we do not yet have any significant results related to the surface-mooring component of the project.

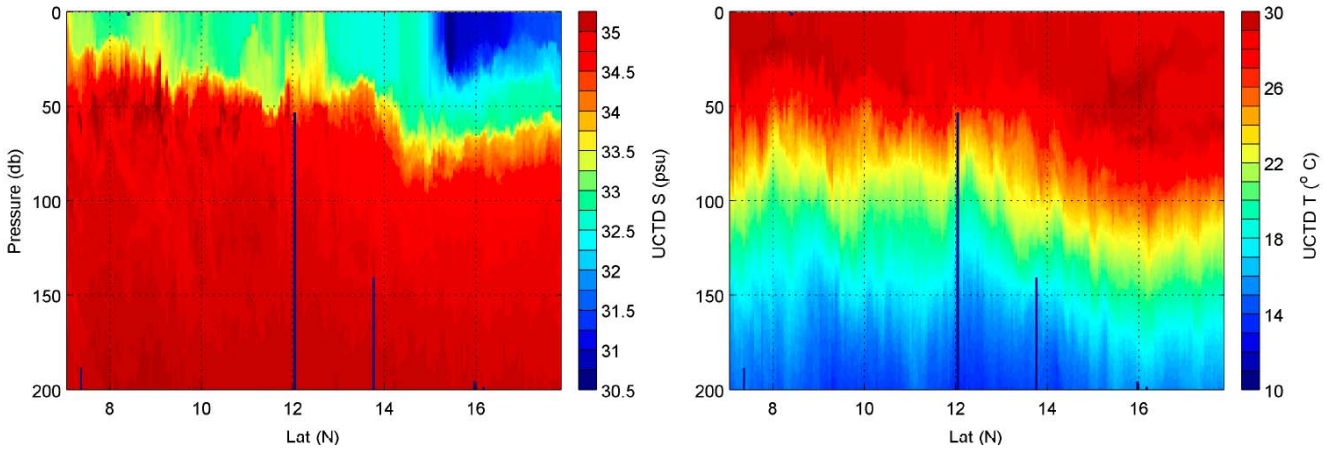

Figure 2: Salinity (left) and temperature (right) from the Underway CTD system during the December 2013 cruise on the RV *Roger Revelle*. The data are from a straight transect referred to as "section B" in Lucas et al. (2014), extending from about 8°N, 85°E (near Sri Lanka) to 18°N, 89°E (near the northernmost point of international waters in the Bay of Bengal).

IMPACT/APPLICATIONS

The data provide a new and detailed view of the spatial variability of the upper ocean in the Bay of Bengal; these data will improve understanding of the space-time variability of the upper ocean in the Bay and will help to refine and focus ONR field campaigns in the region planned for the coming years.

The surface mooring that is scheduled for deployment in November/December 2014 will provide accurate time series measurements of air-sea fluxes of heat, momentum, and freshwater and of upper-ocean (0-100 m) temperature, salinity, and velocity.

RELATED PROJECTS

This project is closely related to the DURIP award, "An Air-Sea Interaction Buoy/Mooring System for Study of Air-Sea Interaction in the Open Ocean" (N00014-13-1-0685; PIs Robert A. Weller and J. Thomas Farrar). The buoy that was constructed under that award is being used for measurements of air-sea fluxes and upper-ocean evolution in the Bay of Bengal for this project.

This project is closely related to several other projects operating under the ASIRI DRI. There is close interaction on scientific goals, hypotheses, and measurements, as well as coordination on logistical matters, such as container shipments to Sri Lanka and India.

PUBLICATIONS

Lucas, A., E. Shroyer, H. Wijesekera, H. Fernando, E. D'Asarso, M. Ravichandran, S.U.P Jinadasa, J. MacKinnon, J. Nash, R. Sharma, L. Centurioni, J. Farrar, R.Weller, Pinkel R., A. Mahadevan, D. Sengupta, and A. Tandon. 2014. Mixing to Monsoons: Air-Sea Interactions in the Bay of Bengal, Eos Trans. AGU, 95(30), 269-270. [published]